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Assessing ‘chaotic eating’ using self-report and the UK Adult National Diet and Nutrition  
Survey: no association between BMI and variability in meal or snack timings

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## Abstract

Although regular meal timings are recommended for weight loss, no study has characterised irregularity in the *timing* of eating occasions or investigated associations with body-mass index (BMI). Here, we characterise ‘chaotic eating’ as the tendency to eat at variable times of day. In two studies, we used a novel measure to explore the relationship between BMI and chaotic eating. In Study 1 ( $N = 98$ ) we measured BMI and used a self-report measure to assess the usual range of times that meals and snacks are consumed over a seven-day period, as well as meal and snack frequency. A separate meal and snack ‘chaotic eating index’ was derived from the number of possible thirty-minute snack- or meal-slots, divided by the frequency of these eating events. After adjusting for age, gender, and dietary habits (Three-Factor Eating Questionnaire) we found no relationship between BMI and chaotic eating of meals ( $\beta = -0.07, p = 0.73$ ) or snacks ( $\beta = -.10, p = 0.75$ ). In Study 2, we calculated the same chaotic eating index (meals and snacks) using data from the UK National Diet and Nutrition Survey of adults 2000-2001 (seven-day diet diaries;  $N = 1175$ ). Again, we found little evidence that BMI is associated with chaotic eating of meals ( $\beta = 0.16, p = 0.27$ ) or snacks ( $\beta = 0.15, p = 0.12$ ). Together, these results suggest that irregular eating timings do not promote weight gain and they challenge guidelines that recommend regularity in meal timings for weight loss.

**Keywords:** Chaotic Eating, Irregular eating, Meal Timings, BMI, Obesity

## 1. Introduction

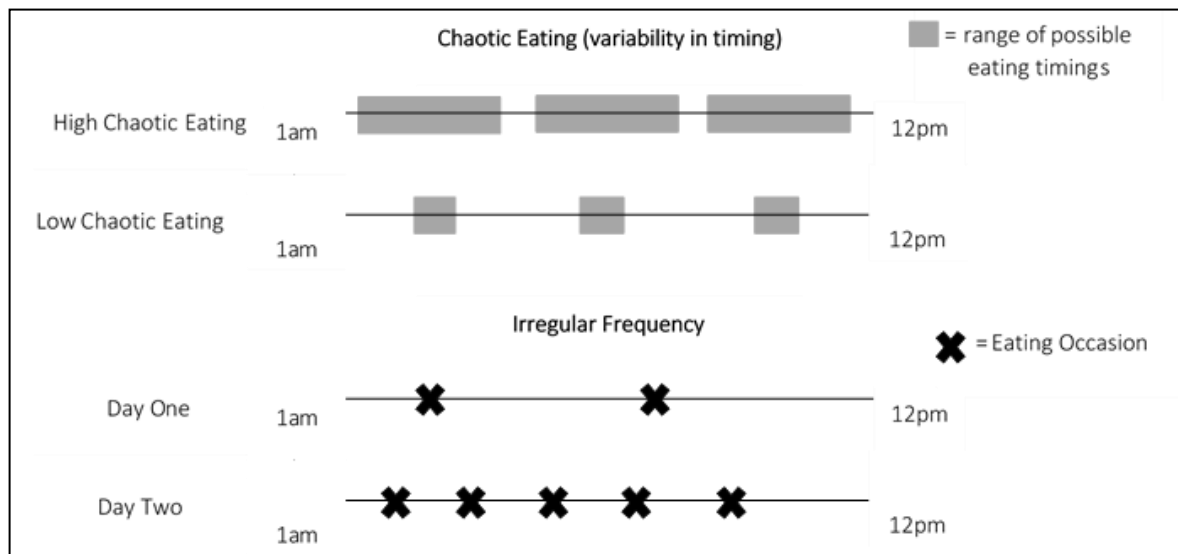
Day-to-day patterns of food intake are thought to play an important role in determining chronic energy balance, and researchers have taken an interest in specific ‘eating

patterns' that might promote obesity<sup>1</sup>. Obesity-related eating behaviours are often described as 'nibbling', 'picking', 'grazing', 'between meal snacking', and 'unstructured' eating<sup>2</sup>. Irregular eating is also considered a risk factor for junk food consumption<sup>3</sup>, weight gain<sup>4</sup> and obesity<sup>5</sup>. However, researchers use different definitions and measures of irregularity. Some have assessed irregularity or variability in the size of specific meals and snacks, while others have assessed total energy intake from one day to the next. The latter is found to be positively associated with BMI and this has been attributed to variability in the size of evening meals<sup>6, 7</sup>. Alternatively, irregularity has been described as variability in the day-to-day frequency of eating occasions. These studies indicate that the effect of irregular eating frequency may be meal specific. For example, a positive association has been observed between BMI and irregular breakfast consumption<sup>8-10</sup>, but not with an irregular frequency of other meals<sup>11</sup>. In controlled studies, irregular eating frequency is found to increase energy intake, to decrease the thermic effect of food<sup>12-14</sup>, and to reduce insulin sensitivity<sup>14, 15</sup>. Other studies show that those who self-classify themselves as having an irregular eating frequency tend to have a higher BMI<sup>16, 17</sup>, a higher prevalence of metabolic syndrome, and increased insulin resistance<sup>18</sup>.

Until now, studies have neglected irregularity in the *timing* of eating occasions. In several countries, including the UK, Australia, and Canada, regular meal timings are recommended for weight loss<sup>19-21</sup>. Similarly, cognitive behavioural therapies for binge eating and obesity prescribe a regular, structured, meal pattern<sup>22, 23</sup>. However, a systematic review of eating patterns and obesity found no evidence to support the hypothesis that irregular eating timings promotes weight gain<sup>24</sup>. For the first time, we report two studies that sought to explore the relationship between BMI and irregularity in the timing of eating occasions. The expression 'irregular eating' has multiple, distinct definitions; hence, we introduce the term 'chaotic eating' - reflecting variation in the *timing* of eating occasions. See Figure 1 for a

visual depiction of the difference between high and low chaotic eating (variability in timings), and how it differs from irregular day-to-day eating frequency.

Figure 1. Visualisation of the concept of chaotic eating (variability in the timing of eating occasions) compared to irregular eating frequency). Differences in the range of possible meal-timings of a high and low chaotic eater are depicted whilst eating frequency is constant at 3 times a day. In addition, the figure shows irregular day-to-day eating frequency, to illustrate how this differs from chaotic eating.



We hypothesised that chaotic eating would be positively associated with BMI. There is speculation that high variability in the timing of eating occasions allows individuals to obtain food at any time, which encourages overeating<sup>25,26</sup>. A chaotic lifestyle, in which eating timings are more variable, might impair an individual's ability to plan the timing of future meals. Eating at unplanned times of day might create uncertainty about when food will next be available. In turn, this uncertainty might lead to the selection of relatively large meals, in order to reduce the likelihood that hunger is experienced during a potentially long inter-meal interval. Previously, a negative association has been observed between BMI and sensitivity to a manipulation of fixed<sup>27</sup> and uncertain inter-meal intervals<sup>28</sup>, suggesting that individuals with a high BMI are less likely to plan for future meals. Chaotic eating, and failure to plan, might also increase the likelihood that individuals will succumb to emotional or external food cues and triggers. Some evidence suggests that weight gain is evident in people who are

71 especially cue reactive or who tend to engage in ‘emotional eating’<sup>29, 30</sup>. To explore how  
72 chaotic eating relates to these traits, we assessed relationships between chaotic eating and  
73 established measures of external and emotional eating. In addition, we explored the  
74 association between restrained eating and chaotic eating. We predicted that restrained eaters  
75 might plan for future energy intake and eat less spontaneously.

76 Circadian timing of food intake could also be a pathway whereby chaotic eating could  
77 influence BMI. Studies link the timing of meals to weight regulation<sup>31</sup>, as well as glucose  
78 control and insulin secretion<sup>32</sup>. Studies report more successful weight loss outcomes among  
79 obese women with a flatter, less fragmented circadian rhythm pattern<sup>33</sup>. Research on temporal  
80 eating patterns demonstrates that evenly spaced meals of the same size are associated with  
81 better diet quality<sup>34</sup>, and a ‘grazing’ temporal eating pattern is associated with poorer diet  
82 quality and adiposity among women<sup>35</sup>. Similarly shift workers, who eat at unusual, possibly  
83 irregular hours, tend to have a higher risk of cardiovascular disease<sup>36</sup> and obesity. These  
84 studies suggest energy intake regulation is linked to the circadian clock. Furthermore,  
85 evidence suggests that meal timing also regulates circadian rhythms<sup>37</sup>. One possibility is that  
86 variable meal timings could lead to more fragmented circadian rhythms, which could  
87 promote weight gain.

88 In this study, we present a novel measure of chaotic eating, reflecting variability in the  
89 timings (30-minute time slots) of eating occasions. Results are reported from two  
90 experiments that investigated chaotic eating in participants with a broad range of BMI. In an  
91 initial study, we measured self-reported chaotic eating of both meals and snacks in  
92 participants with a range of BMIs. In a second study, we used seven-day weighed National  
93 Diet and Nutrition Survey (NDNS) diaries from a representative sample of UK adults to  
94 assess the relationship between BMI and chaotic eating of meals and snacks, accounting for  
95 under-reporting of energy intake. In both studies, we predicted that chaotic eating of meals

and snacks would be positively associated with BMI. Additionally, in Study 2, we assessed whether total energy intake mediated the relationship between chaotic eating and BMI. To understand how chaotic eating relates to eating behaviours that might promote or modify weight gain, we assessed measures of restrained eating, hunger, and disinhibition in Study 1, and we assessed measures of external eating, emotional, and restrained eating in Study 2.

## 2. Study 1

### 2.1 Method

#### 2.1.1. *Participants*

Participants ( $N = 115$ ; 63 women, 51 men, 1 transgender) had a mean age of 32.9 years ( $SD = 10.9$ ) and a mean BMI of  $28.4 \text{ kg/m}^2$  ( $SD = 6.9$ ). All participants were members of the public and not students, and were recruited through our laboratory volunteer database. To reduce demand awareness, participants were told that the purpose of the study was to explore “the relationship between food choice and mood.” Participants were excluded if they were 1) not fluent in English, 2) taking any medication that might influence appetite or metabolism (with the exception of oral contraceptive pills), 3) vegan or vegetarian (this data was collected as part of a larger study which involved non-vegetarian/vegan foods), or 4) allergic or intolerant to any food. Participants completed an initial pre-screening questionnaire, which included an assessment of their height, weight, age, and gender. Based on these self-reported data, participants were classified as in the “normal” range ( $\text{BMI} < 25 \text{ kg/m}^2$ ), overweight ( $25 \text{ kg/m}^2 < \text{BMI} < 30 \text{ kg/m}^2$ ), and obese ( $\text{BMI} > 30 \text{ kg/m}^2$ ). From these responses, we selected a sample with a wide range of BMI. The final sample comprised 47 in the “normal” range, 33 overweight, and 35 participants with obesity. We received informed consent from all participants and they received £30 (sterling) for participating in the study.

119 The protocol was approved by the University of Bristol Faculty of Science Human Research  
120 Ethics Committee.

### 121 2.1.2. Chaotic eating

122 Participants were asked to select all possible times at which they might eat a meal.  
123 Participants were shown a range of tick boxes labelled with half-hour intervals on a 24-hour  
124 clock. In turn, they responded to the question “For a typical week, when is it conceivable you  
125 might eat a meal? If the timing of your meals varies considerably, just select more times  
126 where it is conceivable you might eat. For example, if you might eat a meal between 12pm  
127 and 2pm, select all times from 12-2pm, i.e. 12:00, 12:30, 13:00, and 13:30.” Participants were  
128 then asked to report their meal frequency, “On a typical day, how many times would you eat  
129 a meal?” These measures were then repeated with otherwise identical questions related to  
130 snack consumption.

131 Chaotic eating can be assessed by establishing the number of different 30-minute slots  
132 during which an individual eats over the course of a week. However, the number of unique  
133 slots will increase with a higher frequency of eating occasions. Eating frequency, defined by  
134 the number of occasions an individual eats<sup>38</sup>, is conceptually different from chaotic eating.  
135 For example, a person may report six unique time slots when a meal is consumed over a  
136 week. However, if that person eats six meals a day, then there is no variation in the timing of  
137 these meals, hence they would be considered frequent, but not chaotic. Conversely, if they  
138 report eating a meal at six different time slots over a week, but only eat one meal a day, they  
139 would be considered an infrequent eater who consumes meals at variable times. Therefore,  
140 to establish a measure of chaotic eating that captures variability in the timing of individual  
141 eating occasions, we divided the number of possible meal 30-minute time slots across a week  
142 by the frequency of meals. We also included a measure of chaotic snacking. A snack chaotic



143 eating index was derived in the same way. A high chaotic eating index indicates high  
144 variability in the number of different 30-minute time slots.

### 145 2.1.3. *TFEQ*

146 Dietary behaviour was assessed using a computerised version of the  
147 Three Factor Eating Questionnaire (TFEQ)<sup>39</sup>. The instrument contains 36 items with a yes/no  
148 response format, 14 items on a 1-4 response scale and 1 categorical, 5-point rating. The  
149 TFEQ comprises three sub-scales. 'Cognitive restraint' (conscious control of food intake to  
150 control body weight), 'disinhibition' (loss of control over intake) and 'hunger' (subjective  
151 cravings and feelings of hunger). Higher scores indicate greater disinhibition, hunger and  
152 cognitive restraint.

### 154 2.1.4. *Procedure*

155 In a laboratory setting, participants completed a computerised version of the chaotic  
156 eating questions, followed by the TFEQ and then provided a measure of their height and  
157 weight. BMI was calculated from measured weight/height<sup>2</sup>. As this experiment was part of a  
158 larger study, participants were tested for approximately two hours. Measures included an  
159 inter-meal interval sensitivity task, delay discounting<sup>27</sup>, food choice, and interoceptive  
160 awareness tasks. These measures were used to test unrelated hypotheses. At the end of the  
161 study the participants were debriefed, compensated and thanked for their assistance.

### 162 2.1.5. *Data analysis*

164 BMI and chaotic eating scores were not normally distributed, as assessed by  
165 Kolmogorov-Smirnov test ( $p < .05$ ). Therefore, Spearman's rank-order correlations were  
166 used to assess pairwise comparisons with these variables. All other associations were  
167 assessed by deriving Pearson's correlation coefficients. To test our primary hypothesis, that

chaotic eating would be positively associated with BMI, we conducted a multiple regression analysis. In a regression analysis, both chaotic eating of meals and snacks were entered as predictors in the same model, with BMI as the dependent variable. Age, gender and TFEQ subscale scores were also included as predictors in the regression analyses. Unstandardized betas ( $\beta$ ) from these models are presented. We inspected residual P-P plots to assess whether the regression model fitted the non-normal data. Analyses were completed in SPSS version 23 (SPSS, Inc., Chicago, IL, USA).

## 2.3. Results

### 2.3.1 Participant characteristics

We excluded 17 participants who had missing data on both chaotic eating measures. The final dataset comprised 98 participants (55 women, 43 men), who had a mean age of 33.4 years ( $SD = 10.9$ ) and a mean BMI of  $27.5 \text{ kg/m}^2$  ( $SD = 5.1$ ; See Table 1). Of these, 30 had a BMI in the “normal” range, 40 were overweight and 28 were people with obesity.

Table 1. Mean, standard deviation ( $SD$ ) and range for participant characteristics, number of snack and meal 30-min slots, frequency, and snack and meal chaotic eating index ( $N = 98$ ).

	Mean ( $SD$ )	Range (min-max)
Age (y)	33.4 (10.9)	18 – 55
BMI ( $\text{kg/m}^2$ )	27.6 (5.1)	18.6 – 40.6
TFEQ- Disinhibition	8.1 (3.4)	1.0 – 15.0
TFEQ- Restraint	8.5 (4.9)	0.0 – 27.0
TFEQ- Hunger	7.2 (3.8)	0.0 – 15.0
Number of Snack Timings (30-min time slots per week)	16.4 (9.5)	7.0 – 63.0

Number of Meal Timings (30-min time slots per week)	19.7 (5.4)	7.0 – 49.0
Snack Frequency (snacks per day)	3.8 (4.5)	1.0 – 25.0
Meal Frequency (meals per day)	2.8 (0.9)	1.0 – 7.0
Snack Chaotic Index (30-min time slots per snack)	2.3 (1.9)	0.2 – 10.0
Meal Chaotic Index (30-min time slots per meal)	3.2 (2.5)	0.5 – 12.5

### 2.3.2 Correlations between BMI, chaotic eating, TFEQ, and age

The relationship between BMI and chaotic snack consumption was weak and not statistically significant ( $\rho = -0.11$ ), as was the relationship between BMI and chaotic meal consumption ( $\rho = -0.01$ ). There was little evidence that chaotic snack and meal consumption correlated with TFEQ-disinhibition or hunger. Chaotic snack consumption was negatively correlated with TFEQ-restraint. BMI was positively correlated with age, and with TFEQ-disinhibition and hunger scores, but not with dietary restraint (see Table 2).

Table 2. Spearman's ( $\rho$ ) and Pearson's ( $r$ ) correlations between BMI, snack and meal chaotic eating index, TFEQ-disinhibition hunger and restraint, and age from Study 1.

	BMI	Snack Chaotic Eating Index	Meal Chaotic Eating Index	TFEQ – Disinhib ition	TFEQ – Restraint	TFEQ – Hunger	Age
BMI ( $\rho$ )		-0.11	-0.01	0.28**	.10	.27**	0.16
Snack Chaotic Eating Index ( $\rho$ )			0.02	-0.07	-.25*	-0.06	-0.20

Meal Chaotic Eating Index ( <i>rho</i> )	-0.04	-.02	-0.13	-0.03
TFEQ – Disinhibition ( <i>r</i> )		0.10	0.67**	-0.23*
TFEQ – Restraint ( <i>r</i> )			0.14	-0.24
TFEQ – Hunger ( <i>r</i> )				-0.14
Age ( <i>r</i> )				

\*  $p < 0.05$

\*\*  $p < 0.001$

### 2.3.3. Relationship between chaotic eating and BMI

In a model adjusted for age, gender and TFEQ subscales, evidence failed to support an association between BMI and chaotic meal consumption ( $\beta = -0.07$ ,  $p = 0.73$ ) or chaotic snack consumption ( $\beta = -.10$ ,  $p = 0.75$ ). The model predicted 15% of the variance in BMI ( $R^2 = 0.18$ ,  $F(7, 95) = 2.7$ ,  $p = 0.02$ ). Despite the non-normal distribution of BMI, upon inspection of the distribution of residuals using P-P plots, the regression model was a good fit to the data. To summarise how chaotic eating relates to BMI for graphical purposes, we used ANCOVAs to derive model estimated marginal means and standard error of BMI in chaotic eating quartiles (snacks and meals), when TFEQ subscales and age were controlled for. The linear trends for chaotic eating quartiles (snacks and meals) are displayed in Fig 2.

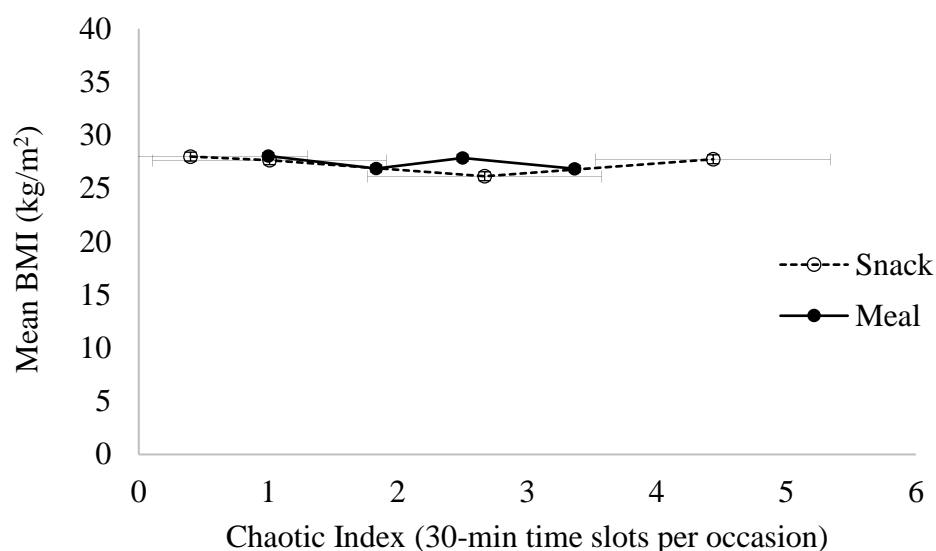


Figure 3. Relationship between BMI and chaotic snack and meal consumption for Study 1. ANCOVAs were used to derive model estimated marginal means and standard error of BMI at chaotic eating quartiles (snacks and meals), after controlling for age, gender and scores on the TFEQ. Chaotic eating index scores were separated into four equal quartiles. Error bars represent  $\pm 1$  SEM.

## 2.4 Interim Discussion

This study used a novel index to assess chaotic eating, reflecting variability in the times of meals and snacks. Against our hypothesis, we observed little evidence for a relationship between BMI and chaotic eating. Chaotic eating of meals and snacks was not associated with TFEQ disinhibition or hunger, but chaotic consumption of snacks correlated with lower dietary restraint.

One possibility is that our findings reflect an error or bias in self-reported eating habits. Assessing dietary behaviour using self-report questionnaires has been a longstanding problem in nutritional research<sup>40</sup>; people are prone to misreporting both their dietary intake and patterns<sup>41, 42</sup>. As we could not assess the validity and reliability of our chaotic eating measure, in a second study we assessed evidence for a relationship between BMI and chaotic eating using data from seven-day weighed diet-diaries, where misreporting of energy intake can be quantified.

### 3. Study Two

In our second study, we analysed the relationship between BMI and chaotic eating of meals and snacks, in a representative sample of UK adults, using seven-day weighed diet diaries from the National Diet and Nutrition Survey (NDNS). In addition, we assessed associations between BMI, chaotic eating and energy intake. To explore how chaotic eating relates to eating behaviours that might impact BMI, we included measures of emotional, external and restrained eating drawn from the subsections of the Dutch Eating Behaviour Questionnaire (DEBQ)<sup>43</sup>.

#### 3.1. Methods

##### 3.1.1. Participants

The National Diet and Nutrition Survey (NDNS) 2000 is a cross-sectional survey of a nationally representative sample of UK adults (aged 19–64 years). A multistage random probability design was used to selected people living in private households across the UK. The survey asked questions focused on diet, nutritional status and nutrient intake. Specific details of the design and data collection can be found elsewhere<sup>44</sup>. In brief, trained interviewers asked participants to complete a 7-day weighed diet diary. All interviews were conducted over a 12-month period in 2000/2001. Ethical approval for the NDNS was obtained from the Multi-Centre Research Ethics Committee and National Health Service Local Research Ethics Committee covering each of the 152 postcodes areas in the sample. Data were accessed from the UK data archive<sup>44</sup>. Researchers measured, height and weight to calculate BMI. The adult respondents of the NDNS were 19–64 years old and 94% of the sample was White British.

##### 3.1.2. Diet Diaries

Multi-day weighed diet diaries require participants to precisely weigh and prospectively record all food and beverages consumed, as well as the timing of consumption over several days. When compared to dietary recall interviews, food frequency questionnaires or urinary biomarkers, seven-day weighed diet diaries are considered a the most accurate estimate of food intake, as they avoid issues with relying upon participants' retrospective reporting or bias in the inaccurate estimation of portion size<sup>45, 46,47</sup>.

### *3.1.3. Classifying intake occasions as meals*

Following previous methods<sup>48</sup>, intake occasions were classified as meals using food group combinations<sup>49</sup>. All NDNS food groups were classified into meal or snack food lists (File 1), based on frequently consumed foods during meals<sup>49-51</sup>. For example, a pizza would be on the meal list, whereas a banana would be on the snack list and a smoothie would be on the drink list. Intake occasions were classified as a meal if all food items were from the meal list, or if at least one food item was from the meal-list, combined with other items from either the snack or drink list. Intake occasions were classified as a snack if all food items were from the snack list, or if at least one food item was from the snack-list, combined with other items from the drink list. Drinks on their own or with supplements were not considered as intake occasions for this study.

### *3.1.4. Calculating chaotic eating*

To measure chaotic eating, we calculated the variability in the number of different meal timings across the week. Initially, mirroring Study 1, we separated the timings of meal into 30-minute time slots. For example, if a meal was eaten at 9:08, they were classified as 9:00-9:30; if a meal was eaten at 9.42, this was classified as 9:30-10:00. For each participant, we totalled the number of 30-minute periods in which they ate a meal across the seven days. Meal frequency was calculated from the mean the number of meal occasions per day.

Following Study 1, we computed meal chaotic eating index by dividing the number of meal timings by the meal frequency. A higher chaotic eating index represents greater variability in the number of times a meal might be eaten, and therefore a more chaotic pattern of eating. We also calculated a snack chaotic eating, based on the timing and daily frequency of snacks.

To further explore chaotic eating timing, we computed the variation in the time intervals (inter-meal interval; minutes) between meals across the week for each participant. Using the time of each meal in minutes since midnight, we calculated the time between adjacent eating occasions within a day. Based on multiple time differences between eating occasions each day, the variation (standard deviation; SD) in the lengths of the inter-meal intervals across the seven days. We hypothesised that high variation in inter-meal interval would also reflect chaotic eating of meals, an expected high correlations between the two measures.

#### *3.1.5. Exclusion criteria*

The initial sample comprised 2251 diary records, however only 1724 participants completed the full dietary record. From these cases, we excluded records with missing DEBQ ( $n = 92$ ) scores and anthropometric data ( $n = 186$ ). Dieters (those who confirmed they were dieting to lose weight during the survey,  $n = 271$ ) were excluded to avoid identifying eating patterns that were not representative of typical behaviours<sup>48</sup>. The final sample size comprised 1175 participants; 557 men and 618 women.

#### *3.1.6. Questionnaires*

Prior to completing diet diaries, participants completed the DEBQ. The 33-item questionnaire assesses three subscales; emotional, restrained, and external eating using a 5-point Likert scale. The DEBQ has high internal consistency, and provides reliable measures for individuals with BMIs in the “normal” range, and people with obesity<sup>52</sup>.



### 3.1.7. Covariates

Self-reported highest education qualification was used as a proxy for socioeconomic status. Following previous analyses<sup>48</sup>, we assessed the extent to which the association between chaotic eating and BMI is mediated by increased total energy intake or confounded by under-reporting. To calculate average daily intake for each participant, we totalled the number of calories reported across the seven days and divided by the number of days. Physical activity diaries were completed where participants reported all activities and their duration for the same 7-days of the dietary diaries. These were used to calculate metabolic equivalent-hours per week (METs)<sup>44</sup>, which were converted to physical activity level (PAL) using standard equations<sup>53</sup> that define participants as sedentary, low active, active or very active. PALs were defined from number of minutes of moderate to vigorous exercise across the week. We calculated estimated energy requirements for each participant based on sex, age, weight, height and PAL. To measure under-reporting, we divided total energy intake of all foods and drinks (TEI) by estimated energy requirements (EER), TEI/EER, which, assuming neutral energy balance, should equal 1.0. To control for random error in the estimation of energy intake and expenditure, we calculated confidence limits of agreement for TEI/EER using variation coefficients. On this basis, participants were defined as either under-reporters (TEI/EER < 0.71) or over-reporters (TEI/EER > 1.29)<sup>54</sup>. We also calculated the total energy intake per day of meals and snacks separately.

### 3.1.8. Data analyses

Snack and meal chaotic eating index and BMI were not normally distributed, as assessed by Kolmogorov-Smirnov test ( $p < 0.05$ ). Therefore, we calculated Spearman's correlations to assess the relationships between BMI and chaotic eating of meals and snacks.

Pearson's correlations were used to assess parametric relationships between total energy intake, DEBQ subscale scores, and age.

To test our primary hypothesis, a multiple linear regression was performed using meal and snack chaotic eating indexes and SD of the inter-meal interval as independent variables and BMI as the dependent variable. To control for age, gender social class, physical activity levels and DEBQ-subscale scores these variables were included (Model 1). To determine whether total energy intake mediated an association between BMI and chaotic eating, total energy intake was also included in a second model (Model 2). We predicted that the association between chaotic eating and BMI would no longer be significant when total energy intake was included as a mediator. Finally, under-reporting category was added to a third model, alongside other predictors from Model 3 (Model 3). Unstandardized betas ( $\beta$ ) from all three models are presented. Thirty-seven participants had missing data for under-reporting, so were removed from Model 3. Analyses were completed in SPSS version 23 (SPSS, Inc., Chicago, IL, USA).

## 3.2. Results

### 3.2.1. Participant characteristics

When classified by BMI groups, the final sample resulted in 24 underweight, 510 in the "normal" range, 426 overweight, and 215 participants with obesity. Participants were defined as underweight ( $\text{BMI} < 18\text{kg/m}^2$ ), normal ( $18\text{kg/m}^2 < \text{BMI} < 25\text{kg/m}^2$ ), overweight ( $\geq 25\text{ kg/m}^2$  &  $\text{BMI} < 30\text{ kg/m}^2$ ) and obese ( $\text{BMI} \geq 30\text{kg/m}^2$ ). See Table 3 for participant characteristics. We classified 217 as under-reporters of energy intake and 921 participants as plausible reporters. 242 had a degree or equivalent (21%), 166 (14.1%) had higher education below degree level, 116 (9.9%) has A level or equivalent, 356 (30.3%) had GCSE grades A-

C or equivalent, 67 (5.7%) has GCSE grades D-E or equivalent, 41 (3.5%) has other qualifications and 187 (15.9%) had no qualifications.

Table 3. Participant characteristics ( $N = 1175$ ; 557 men and 618 women), average daily caloric intake of meals and snacks, moderate physical activity levels (mins), meal and meal frequency, number of 30-min meal and snack timings, and chaotic eating indexes. Means are shown in combination with an associated standard deviation and range.

	Mean ( <i>SD</i> )	Range (min-max)
Age (y)	41.9 (12.0)	19.0 – 64.0
BMI (kg/m <sup>2</sup> )	26.3 (5.1)	15.9 – 67.3
DEBQ- External Eating	2.6 (0.6)	1.0 – 4.6
DEBQ- Emotional Eating	1.8 (0.7)	1.0 – 5.0
DEBQ- Restraint	2.2 (0.9)	1.0 – 5.0
Average Meal Energy Intake (kcal per day)	1357.8 (472.7)	182.2 – 3696.4
Average Snack Energy Intake (kcal per day)	261.1 (201.1)	0.0 – 1464.2
MVPA Levels (minutes)	95.0 (140.5)	0.0 – 747.1
Number of Meal Timings (30-min time slots per week)	10.4 (3.0)	1.0 – 22.0
Meal Frequency (meals per day)	2.5 (0.7)	0.4 – 6.0
Meal Chaotic Eating Index (30-min time slots per meal)	0.61 (0.14)	0.2 – 1.0
Number of Snack Timings (30-min time slots per week)	11.9 (6.2)	1.0 – 35.0
Snack Frequency (snacks per day)	2.5 (1.6)	0.1 – 16.1
Snack Chaotic Eating Index (30-min time slots per snack)	5.4 (1.4)	1.3 – 11.7

DEBQ=Dutch Eating Behaviour Questionnaire; MVPA=Moderate to vigorous physical activity; SD=Standard deviation

### 3.2.2. *Correlations between BMI, chaotic eating, total energy intake and DEBQ subscales*

There was weak evidence for a correlation between BMI and chaotic eating of meals and snacks, though this was not statistically significant, (see Table 4). Chaotic eating of both meals and snacks was inversely correlated with total energy intake. There was evidence that chaotic eating of meals was positively correlated with emotional and external eating scores, and negatively correlated with restrained eating. Chaotic eating of snacks did not correlate with any DEBQ subscales. Chaotic eating index for meals significantly correlated with the SD of inter-meal interval, suggesting both measures reflect similar chaotic and irregular meal timings. BMI was positively correlated with total average energy intake, social class, restrained eating, emotional eating, and age (see Table 4).

Table 4. Spearman's ( $\rho$ ) and Pearson's ( $r$ ) correlations between BMI, chaotic eating index, total daily intake, DEBQ, and age from the NDNS data.

	Meal Chaotic Eating Index	Snack Chaotic Eating Index	Inter- meal interval SD	Average Energy Intake	DEBQ - External Eating	DEBQ - Emotional Eating	DEBQ - Restrained Eating	Age	Education Level)	MVPA (mins)
BMI ( $\rho$ )	-0.05	-0.02	0.01	0.15**	-0.02	0.11**	0.22**	0.23**	0.10**	0.03
Meal Chaotic Eating Index ( $\rho$ )		0.13**	0.30**	-0.27**	0.11**	0.11**	-0.06*	-0.28**	0.01	0.02
Snack Chaotic Eating Index ( $\rho$ )			0.03	-0.08*	0.02	-0.01	-0.01	0.02	-0.06	-0.03
Inter-meal interval SD ( $r$ )				-0.02	0.06	0.26	-0.04	0.01	0.02	0.70
Total Energy Intake ( $r$ )					0.01**	-0.11*	-0.27**	0.05	-0.15**	0.19*
DEBQ – External Eating ( $r$ )						0.49**	0.18**	-0.30**	-0.14**	-0.01
DEBQ – Emotional Eating ( $r$ )							0.29**	-0.17**	-0.07*	-0.09**
DEBQ – Restrained Eating ( $r$ )								0.13**	-0.11**	-0.05
Age ( $r$ )									0.20**	-0.11**
Education Level; ( $r$ )										0.14**

\* =  $p < 0.05$

\*\* =  $p < 0.001$

DEBQ=Dutch Eating Behaviour Questionnaire; MVPA=Moderate to vigorous physical activity; SD=Standard deviation

### 3.2.3 Relationship between chaotic eating of meals and BMI

In multiple linear regression models adjusted for age, gender social class, physical activity levels and DEBQ subscales (Model 1), there was little evidence for an association between BMI and chaotic eating of meals ( $\beta = 0.08$ ,  $p = 0.61$ ) or snacks ( $\beta = 0.13$ ,  $p = 0.19$ ). After adjusting for total energy intake (Model 2), the association between BMI and chaotic eating became slightly stronger but statistical evidence remained weak (meals:  $\beta = 0.15$ ,  $p = 0.32$ ; snacks:  $\beta = 0.16$ ,  $p = 0.11$ ). Adjusting for under-reporting (Model 3), the association with chaotic eating remained insignificant (meals:  $\beta = 0.16$ ,  $p = 0.27$ ; snacks:  $\beta = 0.15$ ,  $p = 0.12$ ). Similarly, there was little evidence for an association between BMI and SD of inter-meal interval ( $\beta = 0.001$ ,  $p = 0.50$ ). The results of the regression indicated that Model 3 explained 16% of the variance in BMI ( $R^2 = 0.16$ ,  $F(11,1137) = 19.38$ ,  $p < 0.001$ ). No evidence of a relationship between BMI and chaotic meal or snack consumption was observed<sup>1</sup>. Despite the non-normal distribution of BMI, upon inspection of the distribution of residuals using P-P plots, the regression model was a good fit to the data. For graphical purposes, ANCOVAs were used to derive Model 4 estimated marginal means and standard error of BMI at equal chaotic eating quintiles, when DEBQ subscales, age, total energy intake and under-reporting were controlled for. See Fig 3.

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<sup>1</sup> Similar results are observed when timings are binned in 1-hour intervals ( $\beta = 0.014$ ,  $p = 0.83$ ).

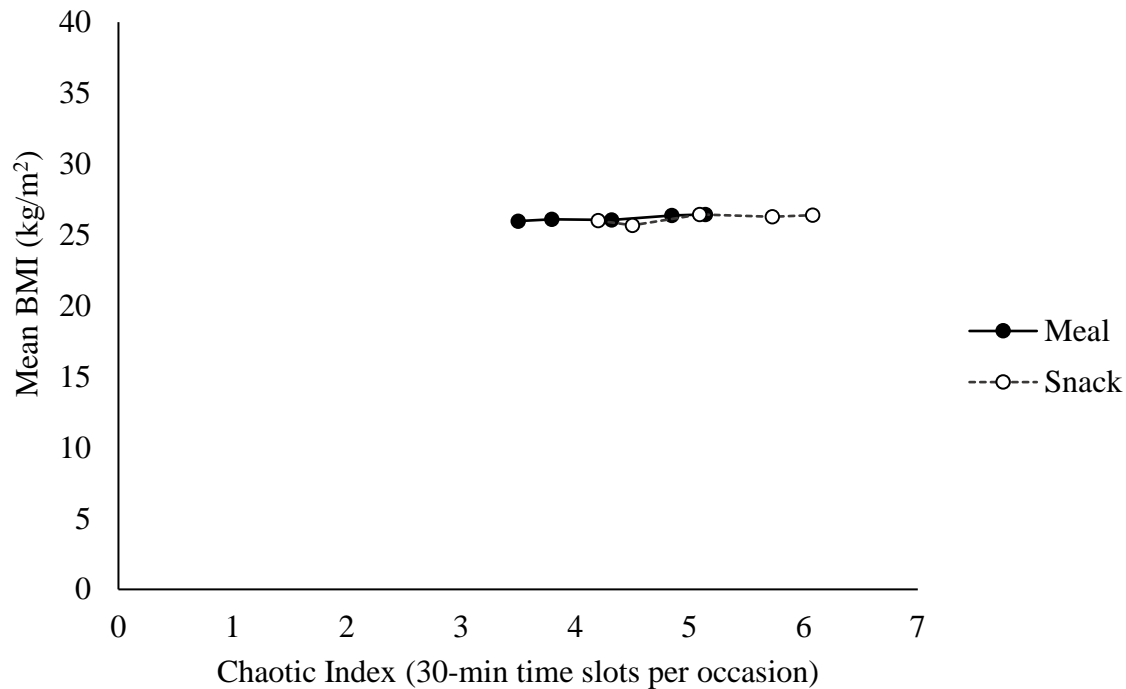


Figure 3. Relationship between BMI and chaotic eating of meals and snacks for Study 2. ANCOVAs were used to derive Model 3 estimated marginal means and standard error of BMI at chaotic eating quartiles, after controlling for DEBQ subscales, age, gender, socioeconomic status, physical activity levels, total energy intake and under-reporting. Chaotic eating indexes were separated into five equal quintiles. Error bars represent  $\pm 1$  SEM.

#### 4. General Discussion

In two studies, we used a novel measure to determine the relationship between BMI and chaotic eating, defined by variability in the timing of eating occasions. In Study 1 we assessed chaotic consumption of meals and snacks based on self-reported timings and failed to show an association with BMI. In Study 2 we derived a measure of chaotic eating using seven-day, weighed diet diaries, and, contrary to our hypothesis, found no evidence for an association between BMI and chaotic consumption of meals or snacks, even when controlling for total energy intake and under-reporting. Similarly, variation in the inter-meal interval across the week, which may also reflect chaotic eating, was not significantly associated with BMI.

In contrast to our hypothesis, that chaotic eating would be associated with high BMI, our findings from both Study 1 and 2 suggest that variability in the timing of meals and snacks is not associated with BMI. Moreover, in Study 2, chaotic eating of meals and snacks were both weakly associated with reduced total energy intake. These results suggest that chaotic eating is not associated with BMI and may even be associated with reduce food intake. Our findings could have implications for dietary recommendations for healthy eating and weight loss<sup>19,20,21</sup> and cognitive behavioural therapies for obesity<sup>22, 23, 55</sup>. Broadly, we found no evidence for an association between chaotic eating and BMI, which is relevant to guidelines that recommend regularity in meal and snack timings for weight loss. More robust evidence is required to inform dietary guidelines to endorse regular meal timings. In the future, we recommend a randomised controlled trial to evaluate the efficacy of this guidance.

Irregular eating patterns have been previously studied as a factor associated with eating behaviours related to BMI and obesity. Studies vary in which aspect of eating architecture is irregular<sup>6-18</sup>; irregular day-to-day eating frequency, self-reported irregular eating, or variability in energy intake per eating occasion has been associated with higher BMI, increased food intake, metabolic syndrome and a reduced insulin response. However, it is regularity in the timings of meals that is typically recommended for healthy eating or weight loss<sup>19,20,21</sup>. As it stands, the evidence for an association between chaotic eating and BMI is weak. Although short-term highly controlled experiments<sup>31, 32</sup> and more ecologically valid, but cross-sectional, observational studies<sup>34,35</sup> have shown that temporal eating patterns and the timing of meals may influence weight regulation<sup>31</sup>, health outcomes<sup>32</sup>, diet quality and adiposity<sup>34,35</sup>, the proposition that regular meal timings promote weight loss currently lacks support from long-term trials in free-living humans. These are a weak form of evidence on which to base any guidelines; prospective observations and RCTs are required as better evidence to support causality.



It is important to note that diet quality may also be an important area of research, considering that the timing of energy and macronutrient intake is associated with diet quality<sup>34,35</sup>. As we did not consider the quality of diets, we cannot make claims about the effects of chaotic eating on diet. Future studies could compare the effects of high vs. low chaotic eating pattern on BMI, food intake and diet quality.

A secondary question relates to whether chaotic eating is associated with other dietary traits. In Study 1 greater restrained eating was associated with less chaotic snacking, suggesting that attempts to limit dietary intake promote regularity. In Study 2, emotional, external and restrained eating were associated with higher chaotic eating of meals, suggesting that variable meal timings reflect a greater tendency to eat in response to external or emotional triggers. However, chaotic eating of meals was weakly associated with reduced energy intake. Surprisingly, chaotic eating of snacks did not correlate with any DEBQ measures. Given these paradoxical findings we are unable to draw firm conclusions about specific dietary styles that might promote chaotic eating or influence food intake. Similarly, chaotic eating was not associated with sample characteristics such as socioeconomic status or physical activity levels. Further research is required to explore how these individual differences might interact with a chaotic eating pattern.

The main limitation of Study 1 is the unknown validity of our measure of chaotic eating. In Study 2, we aimed to address this by using seven-day weighed diaries (widely accepted as a gold standard of dietary assessment) and specifically quantifying under-reporting. The use of nationally representative sample in Study 2 means that the associations we observed can be generalised to the UK adult population<sup>48</sup>. The use of a large sample with a wide range of BMIs and socioeconomic statuses is an additional strength of Study 2, although the data was collected from 2000-2001 so may not reflect present-day meal patterns<sup>48</sup>. The chaotic eating measure does not distinguish between different meals types or

timings; future research could explore how the regularity at specific times might impact caloric intake and BMI. Finally, both studies are cross-sectional, which has a limited ability to draw causal conclusions and as with any observational study the possibility of unmeasured confounding cannot be ruled out.

#### *4.1. Conclusions*

Despite weight loss recommendations that regular, structured eating timings should be adhered to, we failed to show a relationship between chaotic eating and BMI in two studies. We argue that, while regular eating timings may be an important factor in weight loss, such advice is currently lacks support and there is limited evidence that regular meal or snack timings should be recommended. Nevertheless, our findings should be replicated, and we recommend a randomised controlled trial to evaluate the efficacy of this guidance.

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### **6. Conflict of interest.**

The authors declare no conflict of interest. LJ has received funding from Danone Baby Nutrition (2009-2012), Alpro (2015-2016) and Kellogg Europe (2015-2016) for research into dietary intakes, eating architecture and health, which was not directly related to the current research.

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